applied sciences

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Personality Traits Bias the Perceived Quality of Sonic Environments

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Academic Editor: Jian Kang
Received: 30 September 2016; Accepted: 23 November 2016; Published: 3 December 2016

Abstract: There have been few empirical investigations of how individual differences influence the perception of the sonic environment. The present study included the Big Five traits and *noise sensitivity* as personality factors in two listening experiments (n = 43, n = 45). Recordings of urban and restaurant soundscapes that had been selected based on their type were rated for *Pleasantness* and *Eventfulness* using the Swedish Soundscape Quality Protocol. Multivariate multiple regression analysis showed that ratings depended on the *type* and *loudness* of both kinds of sonic environments and that the personality factors made a small yet significant contribution. Univariate models explained 48% (cross-validated adjusted R^2) of the variation in *Pleasantness* ratings of urban soundscapes, and 35% of *Eventfulness*. For restaurant soundscapes the percentages explained were 22% and 21%, respectively. *Emotional stability* and *noise sensitivity* were notable predictors whose contribution to explaining the variation in quality ratings was between one-tenth and nearly half of the soundscape indicators, as measured by squared semipartial correlation. Further analysis revealed that 36% of *noise sensitivity* could be predicted by broad personality dimensions, replicating previous research. Our study lends empirical support to the hypothesis that personality traits have a significant though comparatively small influence on the perceived quality of sonic environments.

Keywords: soundscape; environment; perception; personality; psychoacoustics; *noise sensitivity*; Big Five

1. Introduction

People respond in different ways to the soundscape, the "acoustic environment as perceived or experienced and/or understood by a person or people, in context" [1,2]. Thus, 'acoustic environment' refers to a physical phenomenon and 'soundscape' to a perceptual construct. Differences at societal and cultural levels influence the perception of sonic environments [3–5]. A large survey [6] found that some socio-economic factors, notably occupation and education, were more strongly associated with the perceived sound level than factors such as age, gender, or residential status. At the level of the individual, psychological differences can be charted in terms of broadly defined personality dimensions [7–10] or narrowly defined traits, such as *noise sensitivity* [11–14]. A trait of the latter kind can be described as a "lower order personality construct" ([15], p. 166). A question of interest is the extent to which personality traits, both narrow and broad, influence the soundscape.

The negative impact of environmental noise on health is considerable [16–19]. As an external stress factor, sound has been shown to cause neurophysiological changes in the brain, in particular in regions of the prefrontal cortex, amygdala, and hippocampus, which are involved in cognitive and emotional processing [20]. To some extent, individuals might be able to consciously modulate their cognitive appraisal of an environment ([21], p. 19), but the common belief that people will adapt to sustained high noise exposure levels is not supported by evidence from studies of annoyance among people living close to airports [12,22,23]. However, increased familiarity with an environment that allows for some level of control leads to more positive evaluations [24,25]. A sense of agency might give relevance and meaning to everyday environments [26–28]. The ways people actively regulate their affective relationship with the environment can be understood as coping strategies [29].

Sound activates the autonomous nervous system, causing emotional responses such as relaxation or stress. Changes in heart rate and peripheral skin temperature are correlated with soundscape loudness or evaluative qualities such as calm or chaos [30]. Sudden foreground sounds engage the listener's directed attention reorientation reflex, and chaotic soundscapes do not offer sufficient time in between sonic events for psychological mechanisms, inhibiting arousal to return towards a normal, relaxed state ([31], p. 7). If the soundscape is generally unpleasant, an individual might avoid annoyance by leaving, or avoid fatigue by suppressing the stressor; for example, by putting on headphones while commuting ([24], p. 228) and adjusting sound level and equalisation in order to optimise the listening experience [32]. If on the other hand the soundscape is pleasant, it may allow visitors to regain their default capacity for direct attention restoration. A restorative environment is one that invites undirected mental activities, e.g., sleep and daydreaming, or facilitates aesthetic experiences. Payne [33] showed that an urban park was perceived to have a lower restorative potential than a rural park, yet a higher restorative potential than a grey urban environment. Differences were significant both in a laboratory reproduction setting and in an on-site survey.

McCrae and Costa [8] described personality as a system of basic tendencies, adaptations, and self-concepts, with biological bases (revealed as traits) that are formed by the external environment (revealed as moods, states, or feelings) [9]. Mental processing associated with specific traits is associated with neurological variation in the brain, supporting a biological basis for personality theory [10]. The dimensions in the Five Factor Model, a.k.a. the Big Five, are called *extraversion*, *agreeableness*, *conscientiousness*, *emotional stability* and *openness* (or *openness to new experiences*). The fourth factor sometimes appears in reverse and is then labelled Neuroticism. These constructs originate in the Lexical Hypothesis, which posits that attributes of socially relevant personality characteristics are encoded in natural language, since it is necessary for individuals to communicate traits and states for bonding and, ultimately, for survival (for a historic overview, see [7]).

Noise sensitivity is one of the key constructs in psychoacoustics [34]. It is an aspect of personality that describes the "internal states (be they physiological, psychological (including attitudinal), or related to life style or activities conducted) of any individual which increase their degree of reactivity to noise in general" ([16], p. 59; see also [18]). It is a complex trait that, while being relatively stable over an individual's lifetime, manifests itself differently depending on situation, meaning, attitudes, and motivation [23]. Job [16] suggested that *noise sensitivity* is produced by two latent factors, which make an individual more vulnerable to noise in general: sensitivity to distant, louder noises (e.g., a traffic drone), and sensitivity to close, quieter noises (e.g., a distracting voice). It is a predictor of annoyance [12] but it is independent of noise exposure [16], hearing acuity [13], or a "predisposition to perceive sound events more intensely" ([35], pp. 1471–1472). Because *noise sensitivity* is a self-report measure, it captures an evaluative predisposition towards sounds rather than aspects of auditory processing per se.

Despite a surge in soundscape studies over the past decade, much is still unknown about how individual differences influence the perception of sonic environments. We are not aware of published research investigating the extent to which personality traits can explain ratings of soundscape quality in listening tests, specifically in relation to stimuli variables such as environmental type or loudness. Therefore, the aim of the present work was to address this lacuna of knowledge. We conducted two consecutive experiments: The first involved recordings of urban environments, and the second focussed on restaurants.

2. Methods

2.1. Sound Recordings and Psychoacoustic Descriptors

Soundscape recordings were made using Ambisonic techniques (CoreSound TetraMic, Teaneck, NJ, USA, and SoundDevices 788t, Reedsburg, WI, USA) and transformed to binaural versions suitable for headphone listening (see [36]). Simultaneous on-site sound pressure level (SPL; unweighted $L_{eq,90s}$) was captured with a calibrated Type 1 meter (Extech 407790, Nashua, NH, USA).

From recordings and SPL measurements various audio features were extracted computationally. Psychoacoustic descriptors of time-varying and spectrally complex sounds developed since the 1950s [37,38] have more recently found their way into soundscape research [39–45]. *Loudness* expresses the experience of a sound's intensity and is measured in sone. It is related to acoustic intensity, the distribution of energy in the frequency domain, and time-domain masking phenomena (for details, see [38]; [37], pp. 179–189). *Loudness* was extracted from the B-format omni (W) channel, each file calibrated with the original SPL, using the Dynamic Loudness Model [46] in Psysound3 [47], with values sampled every 0.002 s. See also Section 5.1 Soundscape Indicators, below.

2.2. Quality Ratings

Ratings of soundscape quality were made using the Swedish Soundscape Quality Protocol (SSQP; 41). This protocol asks "To what extent do you agree with the 8 statements below on how you experience the present surrounding sound environment?"; the statements are the adjectives pleasant, exciting, eventful, chaotic, annoying, monotonous, uneventful, and calm. The authors of the SSQP chose these adjectives as the best scale labels to span a circumplex model that they had previously developed. In relation to urban soundscapes, they are assumed to be equally strong semantic concepts. In our implementation of the protocol, listeners rated on continuous scales, anchored by "Agree completely" and "Disagree completely", which were displayed as horizontal sliders with an actual computer screen width of 100 mm. The order of scales on the screen was randomised for each participant and soundscape. Following the theoretic approach behind the circumplex, composite quality scores were calculated from the adjective scales, as follows:

$$\begin{aligned} Pleasantness &= \sum R_{Adj}\cos(2\pi S_{Adj}/8), \\ Eventfulness &= \sum R_{Adj}\sin(2\pi S_{Adj}/8), \end{aligned} \quad (1)$$

where R_{Adj} is a vector of ratings and S_{Adj} is a whole number {0 ... 7} corresponding to the scale's index in the list of adjectives above.

2.3. Personality Traits

Broad personality traits were measured using the Ten-Item Personality Inventory (TIPI; [48]). Despite its brevity, the authors of the TIPI reported good test-retest reliability and convergence to larger instruments. The inventory is headed by the statement "I see myself as ... " which is followed by ten pairs of adjectives, such as "anxious, easily upset" and "extraverted, enthusiastic". Responses are marked on five-point Likert scales anchored by "Disagree strongly" and "Agree strongly". The participants filled out a computer-based implementation with adjectives in randomised order for each person.

Noise sensitivity was measured using Weinstein's Noise Sensitivity Scale (NSS [11] in an adapted version by [14]). It is headed by: "Attitudes to noise. To what extent do you agree with the statements?" and 21 statements including: "I wouldn't mind living on a noisy street if the apartment I had was nice", "When I want to be alone, it disturbs me to hear outside noises", and "I get used to most noises without much difficulty". Certain scales are reverse coded. In our computer implementation, responses are marked on continuous scales anchored by "I totally agree" and "I totally disagree". As before, participants were presented horizontal scales in randomised order. A single-value estimate for *noise sensitivity* is calculated by summing across all scales.

3. Material

The first experiment focussed on urban soundscapes. We selected twelve representative recordings in four *types* of environment, namely Rural parks, Urban parks, Eateries, and Shops. Excerpts of 90 s with a high degree of internal consistency according to informal listening were used. The same stimuli had been employed previously in a different setting [30]. Table 1 gives an overview of their general characteristics.

Table 1. Characteristics of urban soundscapes in Experiment 1. Sound level ($LA_{eq,90s}$) in dB *re* 20 µPa; *Loudness* (N_{10}) in sone. *Pleasantness* and *Eventfulness* = mean scores from Swedish Soundscape Quality Protocol (SSQP) ratings.

Type	Description	Sound Level	Loudness	*Pleasantness*	*Eventfulness*
Rural park	Tropical garden, with faint noises from farm machinery and a distant airplane.	44.5	6.3	1.11	−0.90
	Early morning recording from a nature reserve, with two singing-birds clearly audible.	43.9	7.6	1.05	−0.76
	Mangrove reserve, close to the water, faint city hum in the background.	55.7	14.6	1.20	−0.83
Urban park	Mid-day at a small concrete-and-grass park, with some people resting and a child playing; continuous noise from nearby diesel generator.	74.9	31.7	−1.16	−0.71
	Early evening, with some people sitting on park benches and others passing by; bar music in distance.	54.4	11.3	0.65	−0.70
	Evening at the rooftop garden of a large mall, with groups of young people laughing and chatting.	79.6	44.2	−0.21	0.71
Eatery	Crowded, large and worn-down foodcourt, with noisy fans and plates being scraped.	71.8	29.5	−0.24	0.02
	Well-visited café, with chairs scratching the floor; from outside, church bells and some traffic can be heard.	59.8	14.1	0.33	−0.00
	Crowded street-side restaurants by night, with noise from slow-moving traffic.	68.9	28.3	−0.34	0.44
Shop	Large, old-style market, mid-morning, with sounds of butchers chopping meat.	74.3	38.2	−0.34	0.18
	Large mall between a row of shops and moving escalators. The sound of a child bouncing a ball is audible, and dense traffic in the background.	69.4	25.5	−0.36	0.81
	Very crowded, huge mall in the midst of shop fronts, a cinema entrance, and moving escalators.	81.7	42.5	−0.78	0.79

Experiment 2: Restaurant Soundscapes

The second experiment focussed on restaurant soundscapes, following on from the previous experiment by making finer distinctions within the Eatery type. Restaurants, being a type of servicescape, are characterised by multimodal complexity and more or less elaborate acoustic design [45]. We selected fifteen representative recordings from restaurants in four predetermined environmental *types* according to their design style, a concept that had emanated from a previous study [45]. The *types* were: Café (4 places), Bar (3), MixFusion (4), and Dining (4). Excerpts of 120 s with a high degree of internal consistency according to informal listening were chosen. This set of stimuli was more homogenous in character than the previous one. Table 2 gives an overview.

Table 2. Characteristics of restaurant soundscapes in Experiment 2. Units as in Table 1.

Type	Description	Sound Level	Loudness	*Pleasantness*	*Eventfulness*
Bar	Large mix-fusion bar outdoors near the sea; floor tiles, parasols, beach; medium music; sparse with people.	66.4	21.8	0.99	0.21
	Medium-size mix-fusion bar outdoors near golf court greens; stone tiles, wood tables, open/roofed area; low music; sparse with people.	60.9	21.8	0.06	−1.07
	Very small Western-style bar outdoors near pedestrian walkway and a river; tiles, wood furniture, parasols; low music; practically no people.	61.8	15.9	0.72	−0.85
Café	Medium-size Western-style café; concrete, glass panes, small, entrance from large hospital lobby; medium-level music; medium level of crowding.	74.6	34.8	−0.41	0.46
	Small Western-style café; sofas and chairs, open towards mall; prominent music; extremely crowded	71.0	26.6	−0.58	0.17
	Small Western-style table-served café; wooden floor and furniture, table cloths, glass partition walls, inside open luxory mall; low music; very crowded.	72.0	27.7	−0.02	0.23
	Small international-style café; wood floor, glass panels, medium size, entrance from large mall lobby; medium-level music; medium level of crowding.	72.7	30.5	−0.21	0.10
Mix Fusion	Very large mix-fusion restaurant, outdoor near the sea; canvas roof, stone and wood floor, artificial waterfall in distance; low music; not so crowded.	63.4	17.3	−0.81	0.72
	Large mix-fusion-style restaurant, long wall open to large shopping mall; hard floor, absorbant false ceiling, painted brick walls; low music; sparse with people.	67.7	22.7	−0.05	−0.02
	Small mix-fusion style lunch restaurant; laminate floor, false ceiling, glass panels, medium size; loud music; medium level of crowding.	75.7	33.2	0.03	0.49
	Medium-size mix-fusion style buffet in luxory hotel; hard floor, ceiling treatments, large elongated open area with floor levels, no inner wall separations; low-level music; medium level of crowding.	71.0	26.1	−0.08	−0.46
Dining	Small Taiwanese-style small restaurant; hard surfaces, wooden tables, wall open to large shopping mall; medium-level music; not so crowded	67.3	21.8	0.15	−0.34
	Large Western-style diner entrance inside activity complex; thin carpet, some wood panels on concrete walls, medium size; prominent music; not so crowded.	71.0	27.6	0.03	0.53
	Large Chinese-style fine dining restaurant with entrance from very large mall; hard surfaces, plastic and concrete; low music; medium level of crowding.	62.5	17.2	−0.04	−0.01
	Medium-size Chinese style fine dining restaurant in quiet area country club; carpets, table cloths, curtains; low-level music; medium level of crowding.	66.5	22.3	0.32	0.01

4. Participants and Procedure

Participants in Experiment 1 (n = 43) were university students enrolled in music or sound-related courses. Ages were between 19 and 26; mean 22.0 years; 33 were women. Participants in Experiment 2

(n = 45) were university staff and students enrolled in various programs, aged between 19 and 46; mean 26.1 years; 26 were women. There was no overlap of participants between the two experiments. They consented to participation after receiving full information about procedure and purpose, and received a cinema voucher as a token of appreciation.

The two experiments took place in a laboratory generally suited for sound work. Participants used studio quality circumaural headphones (type AKG K270) with sound playback via a digital audio interface from an individual computer. There was no intermittent disturbance at any time (e.g., heavy rain or construction noise). The participants could listen to stimuli in any order by clicking on graphical objects representing soundscapes. Double-clicking opened a sub-window where ratings were made. They could go back and adjust earlier ratings at any point.

The soundscape recordings had been made at a certain fixed input level and therefore their relative sound levels were correct. However, we did not have access to equipment with which to measure the SPL produced by the headphones at the entrance of the participant's ear canal. Therefore, in Experiment 1, the overall headphone playback level was set at an identical and fixed volume that the experimenter had subjectively found was to be close to the original level at the recording sites. The participants could not change this level. In Experiment 2, headphone playback was calibrated in two steps. First, the sound output of high-quality studio loudspeakers (Genelec 8030) was adjusted to be within ± 1 dB of the original soundscape level, as measured with a calibrated SPL meter (Extech 407790) on A- and C-weighted scales. Second, the experimenter adjusted the headphone level and equalisation to match the SPL of the loudspeakers.

All procedures for data collection were carried out in compliance with approval #2013-05-011 from the Institutional Review Board of Nanyang Technological University, Singapore.

5. Results

5.1. Soundscape Indicators

Several acoustic measures were calculated, referring to the overall level, the level variability over time, and the spectral content of the soundscape stimuli. The analysis reported below follows the approach taken by Axelsson, Nilsson, and Berglund [41]. We included the A-weighted equivalent continuous sound-pressure level in dB L_{Aeq} (excerpts were 90 s in Experiment 1 and 120 s in Experiment 2) and the Zwicker loudness in sone exceeded 10% of the time, N_{10}, as indicators of the overall loudness of the soundscape excerpts. We used the difference between levels exceeded 10% and 90% of the time as indicators of the soundscape variability, either expressed in A-weighted sound pressure-level in dB L_{A10}–L_{A90} or Zwicker loudness in sone N_{10}–N_{90}. We used the difference between A- and C-weighted sound-pressure level in dB $L_{\mathrm{Ceq},x}$–$L_{\mathrm{Aeq},x}$, where x is the duration of excerpts, hereafter $L_{\mathrm{C\text{-}A}}$, as a measure of the relative proportion of low-frequency sound. Tables 3 and 4 show cross-correlations between the five soundscape indicators and the two soundscape descriptors that were extracted from SSQP, namely *Pleasantness* and *Eventfulness*, as described below, averaged across participants. It can be noted that the values are very close to those in Table II in Axelsson et al. [41], which we believe strengthens the validity of our present results.

Table 3. Pearson's coefficient of correlation amount soundscape indicators and descriptors for the 12 urban soundscapes in Experiment 1. For explanations, see text. * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

Indicator	*Pleasantness*	*Eventfulness*	L_{Aeq}	N_{10}	L_{A10}–L_{A90}	N_{10}–N_{90}
L_{Aeq}	−0.90 ***	0.76 **	-	-	-	-
N_{10}	−0.83 ***	0.75 **	0.97 ***	-	-	-
L_{A10}–L_{A90}	0.51	−0.12	−0.34	−0.18	-	-
N_{10}–N_{90}	−0.35	0.63 *	0.63 *	0.75 **	0.34	-
$L_{C\text{-}A}$	0.68 *	−0.73 **	−0.85 ***	−0.79 **	0.12	−0.60 *

Table 4. Pearson's coefficient of correlation amount soundscape indicators and descriptors for the 15 restaurant soundscapes in Experiment 2. For explanations, see text. * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

Indicator	*Pleasantness*	*Eventfulness*	L_{Aeq}	N_{10}	L_{A10}–L_{A90}	N_{10}–N_{90}
L_{Aeq}	−0.55 *	0.77 ***	-	-	-	-
N_{10}	−0.55 *	0.76 **	0.99 ***	-	-	-
L_{A10}–L_{A90}	−0.02	0.67 **	0.26	0.31	-	-
N_{10}–N_{90}	−0.31	0.89 ***	0.79 ***	0.82 ***	0.77 ***	-
$L_{C\text{-}A}$	0.61 *	−0.38	−0.25	−0.22	−0.097	−0.20

5.2. Personality Traits

The scores on Big Five personality traits of the participants in the two experiments were compared with results from a large sample (n = 1813) provided by Gosling and collaborators [48]. Descriptive statistics are provided in Table 5.

For each trait, we tested whether the sample mean diverged from the norm's mean with Mann-Whitney's test. Normality of distributions was tested with Shapiro-Wilk's test; however it should be noted that Gosling does not provide information on distribution shapes and it is therefore not clear if personality traits, as measured by TIPI, are expected to be normally distributed in the population.

Among Experiment 1 participants, no significant difference with the norm was found for any trait (Mann-Whitney U = {370 ... 550}, $p > 0.15$). The distributions were not normal (Shapiro-Wilk W = {0.91 ... 0.95}, p = {0.003 ... 0.042}. Among Experiment 2 participants, *conscientiousness* was slightly different from Gosling's norm (U = 335, $p = 0.04$) while the other traits passed the test (U = {345 ... 542}, $p > 0.05$). Distributions of *conscientiousness* and *openness* were slightly non-normal (both $W = 0.95$, $p = 0.04$) and other traits were normal (W = {0.96 ... 0.96}, p = {0.08 ... 0.54}).

We believe that the overall differences with Gosling's normative sample are small and that the two participant samples are acceptable within the context of an explorative study. Nevertheless, interpretation of results, particularly involving *conscientiousness*, should be made cautiously.

Table 5. Personality characteristics of participants in Experiment 1 and 2, compared with normative data published by Gosling et al. [48].

	Experiment 1 (n = 43)			**Experiment 2 (n = 45)**			**(48; n = 1813)**	
Trait	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**
Extraversion	4.5	1.4	1 ... 6.5	3.8	1.6	1 ... 7	4.4	1.5
Agreeableness	4.9	1.0	2 ... 6.5	5.1	1.1	2.5 ... 7	5.2	1.1
Conscientiousness	5	1.2	2 ... 7	4.8	1.3	2.5 ... 7	5.4	1.3
Emotional stability	5.1	1.1	2.5 ... 7	4.9	1.3	1.5 ... 7	4.8	1.4
Openness	5.4	1.1	3 ... 7	5.3	1.1	2.5 ... 7	5.4	1.1
Noise sensitivity	-	-	-	−4.7	12.5	−29 ... 26	-	-

Composite scores for *Pleasantness* and *Eventfulness* were calculated as described in the Methods section. Unsurprisingly, the perceived quality differences were more pronounced among the urban soundscapes in Experiment 1 than what they were among the restaurant soundscapes in Experiment 2.

5.3. Quality Ratings

The average perceived quality of the sonic environment by predetermined *type* is illustrated in Figure 1. There are parallels between the respective *types* in the two experiments. Rural parks and Bars were rated as most *calm*, while Shops and Cafés were most *chaotic*. The other *types* were rated in between; that is, within their respective contexts, Eateries and Urban Parks, and MixFusion and Dining, were perceived as neutral. The plots reveal that the environmental *types* line up quite close to the *calm*–*chaotic* axis. This suggests that a single perceptual dimension might be sufficient for these types of soundscapes. See [5] for a discussion of soundscape descriptors, and [44] for an interesting approach that involves functional context of environments. More work is needed to rule out an effect of the sampling method, or that the method of calculating composite scores for *Pleasantness* and *Eventfulness* is sub-optimal.

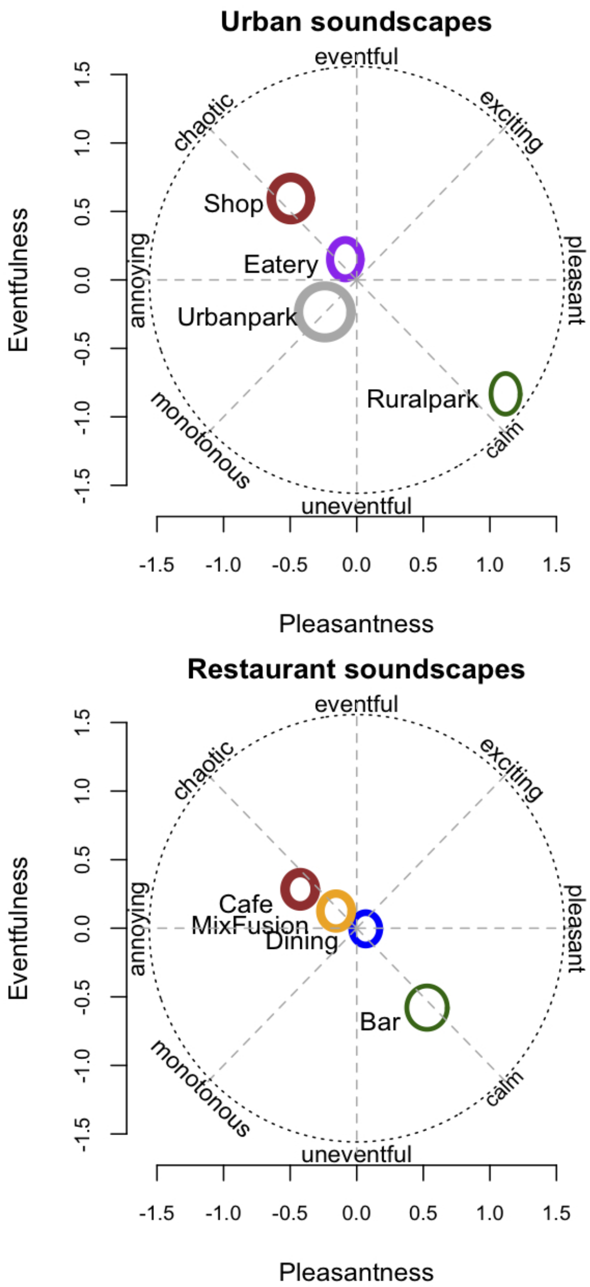

Figure 1. Perceived quality of urban and restaurant soundscape *types* plotted in the *Pleasantness*–*Eventfulness* circumplex. For details, see Methods section. 95% confidence ellipses are plotted, i.e., the ellipses have radii corresponding to 97.5% confidence intervals around means on *x* and *y* axes. The thickness of the ellipse circumference is proportional to the mean *loudness* within the *type*.

5.4. Regression Analysis

The analysis was carried out in three phases: (1) multivariate multiple regression analysis aiming to find the best set of predictor variables among the soundscape indicators included in the cross-correlation analysis above; (2) extending the multivariate model to include personality trait variables as predictors; (3) exploring the relationship between personality traits and soundscape indicator variables in separate univariate multiple regression models.

Please note that in the context of a prediction, no distribution assumptions are required for statistics such as ß, sr^2 (squared semipartial correlation), or R^2 (total amount of variation explained); see Howell ([49], p. 504) for a discussion. However, the probability values attached to these statistics do depend on distribution assumptions such as homoscedasticity, normality, and linearity. This point is important, and since our present data did not fulfil all required assumptions, the interpretation of significance levels and effect sizes of regression models will be tentative. An effect size statistic for sequential multiple regression is given by Cohen [50,51].

In the first analysis phase, we conducted a process of forward stepwise multivariate linear regression analysis aiming to find the best set of independent variables for simultaneous prediction of *Pleasantness* and *Eventfulness* averaged across participants. We considered the five soundscape indicators that Axelsson et al. [41] had reported (N_{10}, L_{Aeq}, N_{10}–N_{90}, L_{10}–L_{90}, and $L_{A\text{-}C}$) and the predetermined soundscape *type* categorical variable. Not unexpectedly, *type* explained the largest amount of variation. In Experiment 1, which had 12 cases, *type* on its own explained 68.2% (multiple R^2) of the variation in mean ratings of *Pleasantness* and *Eventfulness*. In Experiment 2, which had 15 cases, soundscape *type* explained 51.8% of the variation in the two dependent variables.

We then analysed if the predictive model could be improved by the addition of one or more of the acoustic variables. The difference between basic and extended models was tested using ANOVA. In Experiment 1, an extended model with *type* and *loudness* (N_{10}) as predictors explained 79.1% of the variation in the dependent variables. The increase over the basic model was significant (Pillai = 0.62, $p = 0.05$). In Experiment 2, the amount of variation explained by the extended model was raised to 64.0%, but in this case the increase was not significant (Pillai = 0.37, $p = 0.12$). Adding a third variable did not make any significant improvements and the process was stopped at this point.

In the second phase, we investigated the influence of individual differences on soundscape evaluations and moved from using averaged responses to using all the available data. The personality trait variables have been described previously. Note that since the models in the previous phase predicted average responses, the amounts explained are quite high. Because a certain amount of error is attached to the measurement of individual participant traits, as well as error attached to their individual quality ratings, we expected the multiple R^2 to be lower when all the data were included.

In this situation, the model with soundscape *type* and N_{10} as predictors explained 42.3% of the variation in *Pleasantness-Eventfulness* in Experiment 1, and 20.4% in Experiment 2. However, the point of interest in this analysis phase was to determine the increase in explanatory strength provided by the personality trait variables. In Experiment 1, an extended model where the Big Five variables were added explained 44.7% of the variation in *Pleasantness-Eventfulness*. The increase over the smaller model was significant (Pillai = 0.076, $p < 0.001$), with a small effect size (Cohen's $f^2 = 0.044$). In Experiment 2, an extended model including Big Five and *noise sensitivity* variables explained 23.6%; this represented a significant increase (Pillai = 0.080, $p < 0.001$), likewise with a small effect size (Cohen's $f^2 = 0.041$).

While these results are encouraging it must be recalled that the probability values calculated above are tentative, since we could not show that homoscedasticity and other required assumptions were met. Future research might want to focus on selecting larger participant samples, representative of a population, and assure that distribution assumptions are fulfilled.

In the third and final phase, we carried out four univariate multiple regressions with the extended set of predictor variables. The results are given in Table 6.

In Experiment 1, the model explained 48.5% of *Pleasantness* and 35.2% of *Eventfulness* variance. Note that these amounts are the cross-validated adjusted R^2, and that the relatively small difference compared to overall R^2 indicates that the model is fairly robust [52]. Table 6 also gives 95% confidence intervals around the means for these statistics. In Experiment 2, the amount of variance explained was lower; 22.2% for *Pleasantness* and 20.7% for *Eventfulness*. The lower levels might in part be due to the smaller range of acoustic variation among the restaurant soundscape stimuli.

The *type* of environment was a strong predictor for both *Pleasantness* and *Eventfulness* in the two experiments. Note that since *type* was a dummy encoded categorical variable, standardized beta indicates the amount of difference in the dependent variable associated with a shift from one *type* to another. The values in Table 6 refer to the largest differences, i.e., between Shop and Ruralpark, and Café and Bar, respectively.

Loudness was a significant predictor of *Eventfulness* over and above *type*. Within environments of all the kinds defined in the two experiments, louder soundscapes were perceived as more eventful. As discussed above, note that the probability values and significance levels in the present results must be taken as tentative, since homoscedasticity and other required assumptions were not met. We will continue the interpretation of results with caution, but please keep this limitation in mind.

In Experiment 1 and within its *types*, louder soundscapes were rated as less pleasant. However, *loudness* was not a significant predictor of *Pleasantness* in Experiment 2 when the effect of *type* was partialled out. This needs to be discussed, in particular since the corresponding relation in the study by Axelsson et al. [41] was clearly significant. In our data from Experiment 2, separate analysis of each *type* revealed that the expected negative effect was significant only in Cafés. In Bars, there was a significant effect in the opposite direction: louder Bars were rated as more pleasant. The same tendency was observed in MixFusion, but did not reach significance. Looking at the Eateries in Experiment 1, the negative effect of *loudness* on *Pleasantness* was strong. See also Table 2. The weak or even contradictory results within certain restaurant *types* might be due to the influence of other soundscape factors, such as the kinds of sound sources that are prevalent in an environment rather than their *loudness* [53]. Certain sounds might cue expectations in listeners that cause them to adapt their internalised affective responses. For example, if we hear sounds that let us understand that we are in a bar, then 'loud is good'; but on the other hand, if we hear the sounds of a café or a park, then 'loud is bad'. These effects might be investigated in future work.

Table 6. Regression analysis results for Experiment 1 and 2. R^2 = amount explained. Adj. R^2 = R^2 adjusted for the number of predictor variables. Cross-val. adj. R^2 = mean 10-fold cross-validated adjusted R^2 across 3000 iterations [52], with 95% confidence interval around the mean in parenthesis. ß = standardized beta coefficient. p = probability value. sr^2 = squared semipartial correlation. Note that since *type* is a dummy encoded categorical variable, the numerical values given are for the pair of levels that was associated with the largest shift in the dependent variable. * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

	Experiment 1—Urban Soundscapes (12 × 43 = 516 Cases)						**Experiment 2—Restaurant Soundscapes (15 × 45 = 675 Cases)**					
Statistic	***Pleasantness***			***Eventfulness***			***Pleasantness***			***Eventfulness***		
R^2	0.508	-	-	0.379	-	-	0.247	-	-	0.225	-	-
Adj. R^2	0.498	-	-	0.366	-	-	0.234	-	-	0.212	-	-
Cross-val. adj. R^2	0.485 (0.31 ... 0.65)			0.352 (0.17 ... 0.55)			0.222 (0.09 ... 0.41)			0.207 (0.08 ... 0.39)		
Variable	**ß**	***p***	***sr*²**	**ß**	***p***	***sr*²**	**ß**	***p***	***sr*²**	**ß**	***p***	***sr*²**
Type	0.893	0.000 ***	0.118	0.842	0.000 ***	0.092	1.296	0.000 ***	0.105	0.396	0.003 **	0.052
N_{10}	−0.393	0.000 ***	0.066	0.325	0.000 ***	0.043	0.025	0.615	-	0.395	0.000 ***	0.074
Extraversion	0.005	0.891	-	0.112	0.003 **	0.006	−0.059	0.141	-	−0.081	0.048 *	0.005
Agreeableness	−0.046	0.156	-	−0.065	0.075	-	0.126	0.000 ***	0.013	−0.021	0.549	-
Conscientiousness	0.037	0.250	-	0.044	0.224	-	0.110	0.007 **	0.007	0.023	0.582	-
Emotional stability	−0.111	0.000 ***	0.009	−0.112	0.002 **	0.008	−0.102	0.004 **	0.008	−0.026	0.479	-
Openness	−0.053	0.096.	-	−0.005	0.889	-	−0.018	0.612	-	0.012	0.735	-
Noise sensitivity	-	-	-	-	-	-	−0.262	0.000 ***	0.046	−0.047	0.251	-

The influence of *emotional stability* on *Pleasantness* was significant in both experiments. *Emotional stability* was associated with rating the sonic environment as less pleasant, over and above the effects of *type* and *loudness*. Alternatively, we can say that neuroticism was associated with rating environments as more pleasant. The influence of this trait on the soundscape is illustrated in Figure 2, and discussed more thoroughly below.

Noise sensitivity was significantly and negatively related with *Pleasantness*. In other words, the more noise-tolerant participants were, the higher they rated the restaurant environments in terms of pleasantness, controlling for the effects of *type* and *loudness*. This was an expected finding given well-established theory, thus supported by new empirical evidence in restaurants.

The negative influence of *emotional stability* on *Eventfulness* was strong in the first experiment with urban soundscapes, so that neuroticism was associated with rating these environments as more eventful. It did not reach significance for the restaurant soundscapes in Experiment 2.

The squared semipartial correlation of a predictor indicates the amount of variation it explains in response variable, controlling for other predictors. As Table 6 shows, *emotional stability* and *noise sensitivity* were significant predictors in several univariate cases. The explanatory strength of *emotional stability* was approximately one-tenth of the stimuli variables, *type* and *loudness*, for both *Pleasantness* and *Eventfulness* ratings. *Noise sensitivity* was on its own almost half as strong as environmental *type* in Experiment 2.

Finally, *agreeableness* and *conscientiousness* both had significant influence on *Pleasantness* in Experiment 2 but not in Experiment 1. We cannot at this point advance an explanation, and might return to this question in future research. Overall, the regression results indicate that both broad and narrow personality factors might have a predictable influence on quality ratings. We suggest that individual variation such as personality traits be considered in future research that aims to create robust predictive models of perceived quality of various sonic environments.

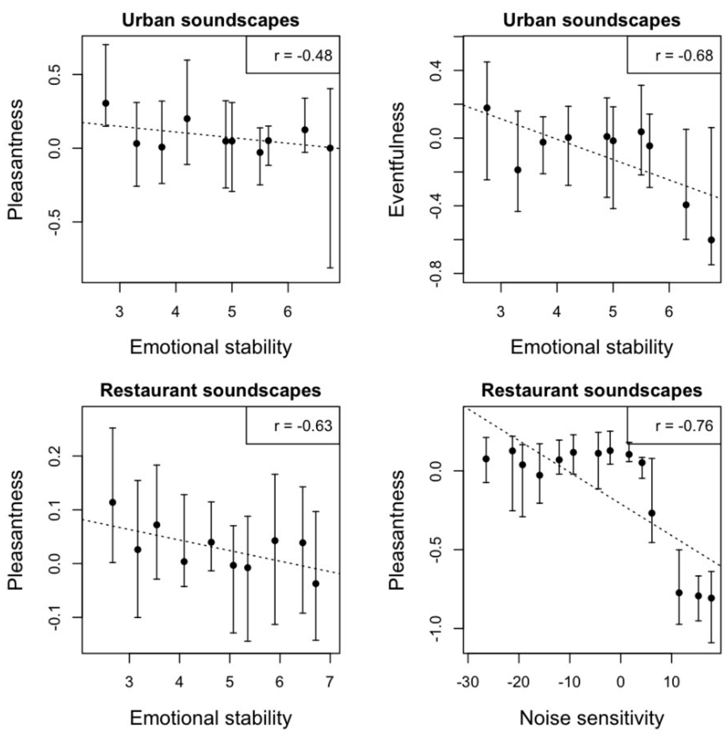

Figure 2. The influence of certain personality factors on ratings of soundscape quality in the two experiments. In the plots, participant trait variables are grouped in equal-sized subdivisions along the *x*-axis, and the median of the response variable within each group plotted with 95% confidence intervals formed by a bootstrap method [52]. For purposes of illustration, linear regression between medians and the middle value of the groups are drawn (dotted lines and Pearson's *r*).

5.5. Relation between Higher and Lower Personality Constructs

Finally, we report results from our data following the investigation by Shepherd and collaborators [15], who hypothesised that *noise sensitivity* might be an expression of underlying and broader personality dimensions. They reported that a linear regression model with the Big Five dimensions as predictors explained 33% of the variance in *noise sensitivity* among their participants. This approach produced very similar results for our data, with 36% (overall R^2) explained. Moreover, the relative strengths of the predictor variables, as indicated by standardised beta, were also similar. As shown in Table 7, each of the broad personality dimensions contributed to *noise sensitivity* in the same directions as in the previous study. Lastly, by taking the beta values they reported, we set up a prediction equation. The correlation between predicted and actual scores in our data was strongly significant ($r = 0.55$, $p = 0.0001$ ***), indicating a robust relationship between broad personality domains and *noise sensitivity*.

Table 7. Prediction of *noise sensitivity* from Big Five traits for participants in Experiment 2. Note that Shephard used the neuroticism construct, which is considered the inverse of *emotional stability*.

Trait	Experiment 2 (*n* = 45)	[15] (*n* = 185)
Extraversion	−0.43	−0.38
Agreeableness	0.05 n.s.	0.25
Conscientiousness	0.46	0.34
Emotional Stability	−0.10 n.s.	−0.19 n.s.
Openness	−0.17	−0.07 n.s.

6. Discussion

In Experiment 1 (urban soundscapes) the stimuli were overall quite similar in character to the ones that Axelsson, Nilsson, and Berglund investigated [41]. This resulted in cross-correlations between perceptual ratings and acoustic variables showing similar patterns in the two studies, as can be seen by comparing Axelsson's Table II with our Tables 4 and 5. The predictive models in the two studies also resemble each other in terms of the variables included and the overall amount of variation explained, as can be seen by comparing Axelsson's Tables III and IV with our results from the first phase of the multivariate regression analysis, reported above. We believe that these parallels strengthen the modelling approach where soundscape indicators of different kinds are included, i.e., both acoustic and psychoacoustic measures, such as *loudness*, and categorical variables that describe more general characteristics. The latter might be a variable emanating from Technological/Human/Natural ratings or a categorical *type* variable such as the one we determined in our initial selection of stimuli.

In both Experiment 1 and Experiment 2, trait *emotional stability* emerged as a significant predictor of *Pleasantness*. Low *emotional stability* (i.e., more neurotic) was associated with high *Pleasantness* ratings over and above soundscape *type* and *loudness*. The predictive strength of this personality trait was similar in both soundscape contexts. Theory holds that neurotic individuals are sensitive to reward and punishment cues and that they are more prone to emotional contagion, i.e., their emotional state is more easily influenced by their appraisal of the environment [5]. Hedonic tone is a concept linked to a neurological mechanism that underpins reward and aversion behaviour, in such a way as to safeguard the individual against unpleasantness when arousal levels soar [54]. Consider also that participants in perceptual experiments may exhibit a tendency for response bias, i.e., to subconsciously adapt their rating in the direction they imagine is preferred by the experimenter. In the present study, those generally more sensitive to reward cues might have exhibited a demand bias, producing higher *Pleasantness* ratings (discussed in e.g. [11,12,55]). Conversely, theory says that individuals who are more emotionally stable tend to use a wider range of emotion words expressing pleasure, thus emphasising the hedonic content of experiences [9].

Noise sensitivity correlated negatively with ratings of *Pleasantness*, which replicates previous findings [15] and is in line with the definition of the construct. Noise-tolerant participants were biased to rate the restaurant soundscapes as more pleasant. Inspection of the third plot in Figure 2 suggests that the relationship might not be linear. The optimum stimulation level theory [56] links evaluative perception of a stimulus to its information rate via a ∩-shaped relationship. Whether a similar mechanism is relevant to *noise sensitivity* might be investigated in the future.

The relationship between lower order *noise sensitivity* and higher order broad personality characteristics is complex. Weinstein [11] found *noise sensitivity* to be associated with intelligence, self-confidence in social interactions, and "desire for privacy", but Iwata [55] reported that highly noise sensitive individuals tended to be less well-adjusted (that is, more neurotic) and less healthy. Stansfeld [13] also found that *noise sensitivity* was associated with mental health problems, in particular depression, and Weinstein [12] (p. 465) reported that it correlated negatively with *extraversion*. However, the relationship might not be straightforward. While Dornic and Ekehmmar corroborated Weinstein's finding for "low and middle extraverts", they reported that the "neurotic extraverts" in their study were highly sensitive to noise [54] (p. 991). On the other hand, stable (i.e., non-neurotic) extraverts might have a higher tolerance for external stressors, and it has been suggested that this is associated with chronically lower levels of cortical arousal in such individuals (see [11] (p. 462); also [23]).

Our present results corroborate the findings by Shepherd et al. [15], producing robust evidence that *noise sensitivity* can be predicted from *extraversion* and *conscientiousness*. Note that *emotional stability* was not a significant predictor in both of these studies. This might indicate that this specific personality trait is relatively independent of *noise sensitivity*; however, an interaction effect of the kind suggested by [54] cannot be ruled out. We believe that future studies might illuminate this question by working with alternative and complementary constructs of *noise sensitivity* that are based on other data than self-report, such as behavioural and psychophysiological measurements.

Because of the modest sample sizes in the listening tests we have conducted, both in terms of the number of stimuli and the number of participants, the present results have limited generalizability. We have shown that the explanatory strength of personality traits in the multivariate regressions was small, yet significant. Thus the influence of some traits might have been drowned in experiment noise. This limitation can be overcome by having larger participant groups, or by targeting specific traits, foremost *emotional stability* and *noise sensitivity*. Moreover, the mechanisms behind how personality traits cause a bias in affective responses to soundscapes are not well understood. This question calls for work in theory as well as empirical approaches, such as comparing cognitive appraisal with individual physiological responses (e.g., [30,57]).

In a recent publication, Aletta, Kang, and Axelsson [5] laid out a roadmap for soundscape research, especially predictive modelling, which forms the basis for planning and design. The authors highlight the distinction between soundscape descriptors (predictants, which enter as dependent variables in a predictive model) and soundscape indicators (predictors, which enter as independent variables that describe stimuli). This perspective is important in the investigation and selection of variables for modelling. In our present work we adopted the SSQP [41] to generate soundscape descriptors (*Pleasantness* and *Eventfulness*), and we selected stimuli variables (*type* and N_{10}, i.e., soundscape indicators) that were either predetermined or significant in the initial multivariate analysis. We have attempted to explain more of the variation in dependent variables (soundscape descriptors) by considering ratings from individual participants. Our results indicate that *Pleasantness* and *Eventfulness* might to a small yet probably significant extent be predicted by personality traits, over and above soundscape indicators.

Trait variables could be seen as moderating variables in a predictive model. Our present results are tentative due to the limitations discussed above; this concerns the effect sizes and probability values associated with regression model statistics (in particular R^2 and sr^2; but note that these statistics themselves are legitimate regardless of variable distributions). These limitations might be addressed in future work, which would also consider a formal analysis of the influence of moderating variables.

A predictive model might include semantic descriptors of sound sources that are relevant and powerful cues for knowing (or imagining) what type of soundscape one is hearing. Because environments are multimodal, non-auditive cues might also be included, notably visual.

People are indeed different, and yet some of the ways in which sound affects us are systematic. Acoustic designers need to be knowledgeable about predictable variation and take it into account when planning for urban spaces and restaurants. Rather than "non-places" [26], people deserve access to healthy places full of meaningfulness, where they can work creatively, communicate, relax, and play.

Author Contributions: PerMagnus Lindborg conceived, designed, and performed the experiments; PerMagnus Lindborg and Anders Friberg analyzed the data and wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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